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Vitamins in Human Nutrition

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Introduction

- Group of organic substances
- Chemically highly diversified
- Exist in foods
- **Needed in small amounts in diet**
- Function in wide variety of capacities
- Not a source of energy
- Essential in minute quantities for:
  - Normal growth
  - Maintenance of life
  - Metabolic processes
  - Chemical and biochemical reactions

Vitamins overview

- When it come to vitamin, we often hear, "**if a little is good, then more must be better**"
- Generally, humans require about 28 g vitamins for 70 kg food they consume
- Plants can synthesize all vitamins they need
- Animals vary in their ability to synthesize vitamins as guinea pigs and humans among few, can not make own supply of vitamin C
- Ancient Greeks treated night blindness with beef liver, rich source of vitamin A
- During 15th and 16th century, British sailors on long sea voyages died from disease **scurvy**

CLASSIFICATION OF VITAMINS

Fat-soluble vitamins

1. Vitamin A
2. Vitamin D
3. Vitamin E
4. Vitamin K

Water-soluble vitamins

1. Vitamin B complex
   - Vitamin B1 (thiamine)
   - Vitamin B2 (riboflavin)
   - Vitamin B3 (niacin/niacinamide)
   - Vitamin B5 (pantothenic acid)
   - Vitamin B6 (pyridoxine)
   - Vitamin B7 (biotin)
   - Vitamin B9 (folic acid)
   - Vitamin B12 (cyanocobalamin)
2. Vitamin C

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Fat soluble vitamins

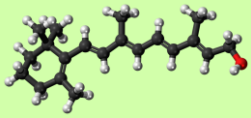
- Soluble in fats
- Supplied through foods containing fats
- Stored where fat deposited
- Excreted exclusively in faeces
- Include A, D, E and K

Vitamin A or Retinol

- Known for more than 3500 years as factor to prevent night blindness
- Egyptians & Greek physician Hippocrates recommend consumption of beef liver to cure night blindness
- Refers to preformed retinoids and provitamin carotenoids converted to vitamin A activity
- Retinoids collective term for biologically active forms of vitamin A
- Exist in 3 forms
  - Retinol (an alcohol)
  - Retinal (an aldehyde)
  - Retinoic acid

Vitamin A or Retinol-Cont..

- Pale-yellow crystalline substance
- Abundant in foods of animal origin
  - Cod liver oil
  - Liver
  - Milk
  - Butter
  - Cheese
  - Eggs



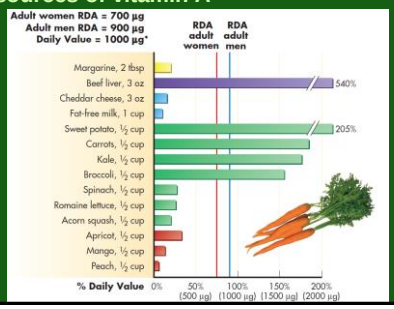
- Carotenoid, yellow-orange pigment in fruits & vegetables act as provitamins
- More than 600 known carotenoids
- Only α-carotene, β-carotene, and β-cryptoxanthin converted to biologically active forms of vitamin A
- Lycopene do not have vitamin A activity in humans

Vitamin A in Foods

- Retinoids (preform vitamin A) exist in liver, fish, fortified milk & eggs
- Carotenoids present in dark green or yellow-orange fruits & vegetables such as carrot, spinach, sweet potatoes, mango, peach and apricots
- Animal sources provide about 70% vitamin A in developed countries peoples diet whereas, plant carotenoids among poor peoples diet

GROUP OF FOODS RICH IN VITAMIN A

Food sources of vitamin A



Vitamin A activity

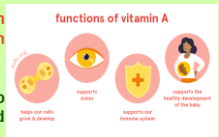
- Dietary vitamin A activity expressed in Retinol Activity Equivalents (RAE)
- One RAE equal to
  - 1 µg of retinol
  - 12 µg of beta-carotene
  - 24 µg of alpha-carotene
  - 24 µg of beta-cryptoxanthin

Table 12-1 Conversion Values for Retinol Activity Equivalents

1 Retinol Activity Equivalent (RAE)	1 IU vitamin A activity
= 1 µg retinol	= 0.3 µg retinol
= 12 µg beta-carotene	= 3.6 µg beta-carotene
= 24 µg alpha-carotene and beta-cryptoxanthin	= 7.2 µg alpha-carotene and beta-cryptoxanthin

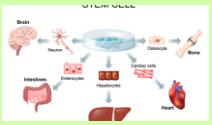
Vitamin A - Functions

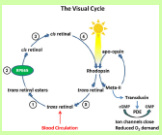
- Anti–infective vitamin
- Essential for normal growth and metabolic process
- Participates in formation of rhodopsin (visual purple), aids eyes to adjust vision in dim or reduced light
- Helps keep skin smooth
- Provides resistance against infection to linings of mouth, nose, throat and digestive tract
- Strengthens mucosal epithelium
- Stored in liver, body draws when needed



Functions of Vitamin A

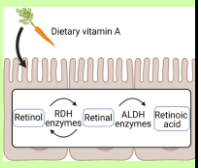
- Vitamin A retinoids perform different functions in human body
- Major functions include
  - Growth and development
  - Cell differentiation
  - Vision
  - Immune function





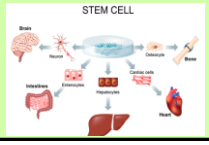
Growth and Development

- Retinoids play vital role in **embryonic development**
- Studies confirmed vitamin A involved in eyes, limbs, cardiovascular and nervous system development
- During early stages of pregnancy, vitamin A deficiency result **birth defects and fetal mortality**
- Retinoic acid necessary for production, structure, and normal function of epithelial cells in lungs, trachea, skin, GI tract, and many other systems
- Important for formation and maintenance of mucous-forming cells in humans



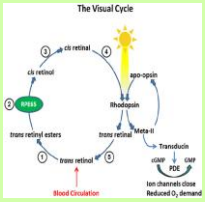
Cell Differentiation

- Process in which **stem cells develop into specialized cells** with unique functions in body
- Vitamin A vital in **normal differentiation** of cells that make structural components of eye, such as cornea (clear lens) and retina (rod and cone cells)
- Also, **retinoids can bind 2 main retinoid** receptors RXR and RAR in nucleus that regulate
  - Formation of messenger RNA (needed to copy genetic material from DNA)
  - Subsequent formation of proteins via gene expression that directs cell differentiation process in effective way



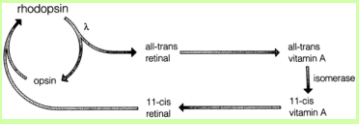
Vision

- Needed in retina of eye to **turn visual light into nerve signals**
- Sensory elements of retina consist rods and cones
- Rods responsible for visual process occur in dim light, translating objects into black-and-white images and detecting motion
- Cones responsible for visual process occur under bright light, translating objects into color images
- In rods, ll-cis-retinal binds to protein called opsin to form visual pigment rhodopsin



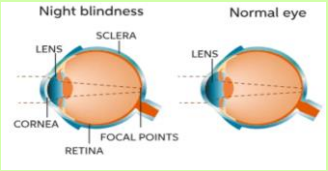
Cont..

- Light absorption catalyze change in shape of **ll-cisretinal causing opsin** to separate
- Separation leads to cascade of biochemical events **trigger change in ion permeability of photoreceptor cells** and initiate signal to communicate with brain's visual center
- During exposure to bright light, **rod's rhodopsin completely activated**, can not respond to more light
- To keep visual process functioning, **all-trans-retinal eventually be converted back to ll- cis -retinal**



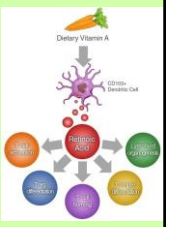
Development of night blindness

- Not all retinal is used in each cycle
- **Some is stored in the eye to maintain vitamin A pools**
- If vitamin A pools become depleted, the process of **dark adaptation impaired**, making it difficult to adjust to seeing in dim light, known as night blindness



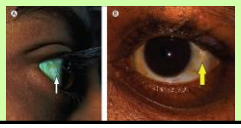
Immune system

- Vitamin A as retinoic acid important for immune system
- Vitamin A deficient individuals have greater **susceptibility to illness and infection**
- As vitamin A helps maintain **epithelium**, a barrier that protects body against entry of disease pathogens
- Epithelium; Covering of internal and external surfaces of body such as lungs, GI tract, blood vessel linings, skin
- Note: In many regions of world vitamin A deficiency is common, vitamin A supplementation is provided to reduce the severity of some infections like **measles and diarrhea etc. in vitamin A deficient children**



Vitamin A Deficiency

- **Major public health problem in developing countries**
- Leading cause of non-accidental blindness, globally
- Deficiency occur in persons with obstruction of **bile duct as bile salts needed for absorption**
- Deficiency result changes in eye especially when retinol in blood insufficient to replace lost during visual cycle, rods in retina regenerate rhodopsin more slowly resulting night blindness
- Without enough **retinoic acid, mucous forming cells deteriorate developing conjunctival xerosis** (abnormal dryness of eye)
- Also produce follicular hyperkeratosis with dry, rough, sandy texture to skin
- In infants and young children, deficiency impair growth

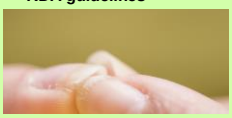


Vitamin A Toxicity

- Excessive consumptions of vitamin A develop hypervitaminosis A
- Toxicity appear with long term supplement use at 5-10 times RDA for retinoids
- Upper Level is 3000 µg/day of retinol to prevent harmful effects
- 3 kinds of vitamin A toxicity
  - Acute
  - Chronic
  - Teratogenic
- **Acute toxicity caused by ingestion of 1 very large dose of vitamin A** or several large doses over few days (about 100 times RDAs)

Vitamin A Toxicity-Cont..

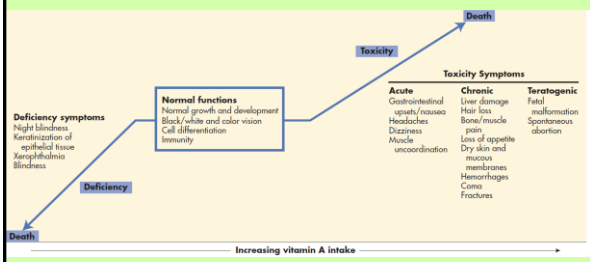
- Acute toxicity effects **GI tract, headache, blur vision, and poor muscle coordination**
- Once the dosing stopped, signs disappear
- Extraordinarily large doses of 500 mg in children and 10 g in adults can be fatal
- In chronic toxicity, infants and adults show wide range of symptoms such as joint pain, loss of appetite, skin disorders, headache, reduced bone minerals, liver damage, double vision, hemorrhage, and coma.
- **Symptoms occur with repeated intakes of at least 10 times of RDA guidelines**



Vitamin A Toxicity-Conti..

- Most serious and tragic effects of **hypervitaminosis A are teratogenic (causing birth defects)**
- A teratogen is an agent that can disturb the development of the embryo or fetus
- Vitamin A and its related analog forms (all trans retinoic acid and 13 cis retinoic acid used to treat disorders
- Women of childbearing age should be cautioned against using these medications
- Consuming carotenoids in large amounts from foods does not readily result in toxicity

Consuming right amount of vitamin A is critical to health



Vitamin A in stability in food products

- Vitamin A and carotenes quite stable
- Unaffected by normal cooking
- Some losses during frying and sun drying
- Oxidation of retinol during storage results in loss
- Losses minimized by use of antioxidants or refrigeration

Vitamin D

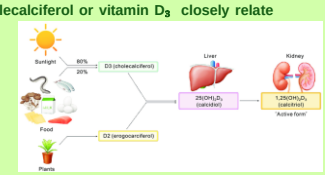
- Bone deformities like rickets caused by vitamin D deficiency described since ancient time
- **Until 1918, scientists cured rachitic dogs (dogs affected with rickets) by feeding cod liver oil, that diet was linked with this disease**
- Soon after, vitamin D discovered and cod liver oil became daily supplement for millions of children
- Cod liver oil common supplement for children in US.. until 1933, when milk first fortified with vitamin D

Cont..

- Most scientists classify vitamin D as a vitamin
- However, in sunlight **presence skin cells can synthesize sufficient vitamin D from derivative of cholesterol**
- If synthesis is adequate to meet needs, vitamin is more correctly classified as a "**conditional**" vitamin, or prohormone (a precursor of an active hormone)
- In absence of UV light exposure, an adequate dietary intake is essential to prevent deficiency diseases
- Rickets
- Osteomalacia

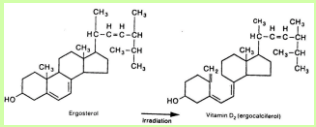
Cont..

- **White crystalline compound and lipid soluble**
- In humans, most important compounds are
- Vitamin D_2 (Ergocalciferol)
- Vitamin D_3 (cholecalciferol)
- Natural form of vitamin D, cholecalciferol or vitamin D_3 closely relate to cholesterol
- Found in:
  - Fish liver oil
  - Eggs
  - Butter
  - Liver
  - Cheese

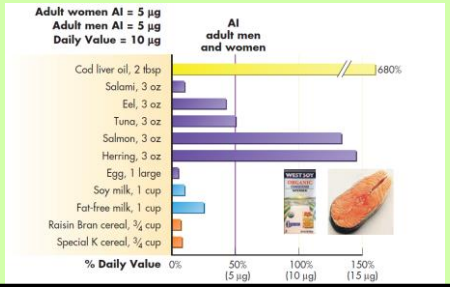


Cont..

- Also produced in human body by UV rays of sun on skin
- Another form, ergocalciferol or D_2 obtained by irradiating vegetable sterol, ergosterol
- Activity expressed in IU.
- one I.U. equivalent to 0.025 µg vitamin D_3
- Stored in:
  - Liver
  - Fatty tissues



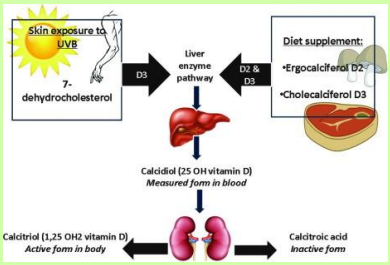
Food sources of vitamin D



Vitamin D_3 Formation in Skin

- Synthesis of vitamin D_3 begins with 7-dehydrocholesterol which is precursor of cholesterol synthesis in skin
- **Sun exposure provide 80-100% of vitamin D_3 body need in humans**
- Amount of sun exposure needed, however, depends on
  - Geographic location, season and Time of day (UV light availability)
  - Age (older age less capacity to produce, 30% capacity at age of 70)
  - Skin color (Melanin in dark-skinned individuals block UV light, prevent adequate vitamin D3 synthesis)
  - Use of sunscreen (Skin cancer)
- Recommendation are to expose UV light at least 2-3 times a week for 10-15 min
- Individuals with dark skin need sun exposure of 30 min or more (or vitamin D supplementation)

Vitamin D_3 Formation in Skin

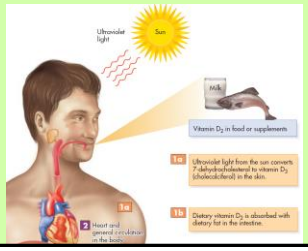


Vitamin D Need

- Food and Nutrition Board set an Adequate intake, rather than an RDA for vitamin D
- More precise RDA level could not set as vitamin D from sun exposure varies considerably among individuals
- Adequate intake for vitamin D is
  - 5 µg/day (200 iU/day) for people under age 51
  - 10 µg/day (400 iU/day) for people between 51 and 70
  - 15 µg/day (600 iU/day) for older adults
  - Older adults and those have limited sun exposure need 20-25 µg (800 to 1000 iU)

Vitamin D from different sources

- Whether synthesized in skin or obtained from dietary sources, vitamin D ultimately functions as hormone: 1,25(OH)2 vitamin D_3 (calcitriol)


Ultraviolet light
Sun
Milk
Vitamin D_3 in food or supplements
1c Ultraviolet light from the sun converts 7-dehydrocholesterol to vitamin D_3 (cholecalciferol) in the skin.
1a
1b Dietary vitamin D_3 is absorbed with dietary fat in the intestine.
2 Heart and general circulation in the body

Vitamin D from different sources

2 Vitamin D from both dietary sources and synthesis in the skin is bound to carrier proteins in the bloodstream and transported to the liver.

3 Vitamin D is converted in the liver to 25-OH vitamin D_3.

4 Vitamin D is converted in the kidney to 1,25(OH)$_2$ vitamin D_3.

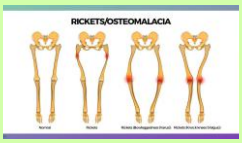
Vitamin D Functions

- Regulate body's concentration of calcium and phosphorus
- Aid in proper utilisation (absorption and metabolism) of Ca and P needed for bones and teeth
- Important for growing children, pregnant and lactating mothers
- Children and adults adequately exposed to sunlight need no dietary vitamin D for good health

functions of vitamin D
helps our muscles contract
helps form & keep strong bones & teeth
helps nerves carry messages between the brain & the body
supports our immune system

Vitamin D deficiency

- Deficiency - Softening of bones
  - Rickets in children
  - Osteomalacia and osteoporosis in adults
- Rickets a disease in growing children
- Inadequate Ca and P in blood for deposition in bone
- Skeleton fails to mineralize normally
- Bones weak and bow under pressure



Vitamin D toxicity

- Toxicity occur from excessive vitamin D intake
- Upper Level of intake (50 µg /day or 2000 IU/day)
- High intakes cause overabsorption of calcium and hypercalcemia
- Excess blood calcium leads to deposits of calcium in kidneys, heart, lungs resulting nausea; vomiting, joint pain; and bones disorientation
- Early stages of toxicity are treatable
- Excess intakes continues leads towards fatal consequences

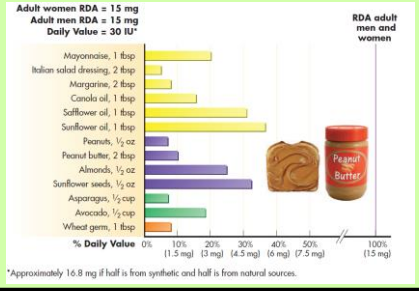
VITAMIN E

- Pale–yellow viscous oil
- Family of 8 compounds known as tocopherols and tocotrienols
- Tocos – child birth, pheros – to bear
- Tocopherols found in foods, especially oil seeds
- Alpha tocopherol most potent form compared to beta, gamma, and delta
- Gamma-tocopherol potentially beneficial form in vegetable oils but less activity
- Natural vitamin E more active, better retained by body than synthetic product

Vitamin E – Sources

- Good sources
  - Cold pressed crude vegetable oils
    - Wheat germ, sunflower, soybean
- Moderate
  - Eggs, butter
- Poor
  - Meat, fruits, green leafy vegetables
- Vitamin E in food depends on harvesting, processing, storage, and cooking
- Highly susceptible to destruction by oxygen, metals, light, frying

Food sources of vitamin E

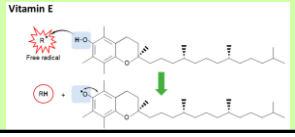

Adult women RDA = 15 mg
Adult men RDA = 15 mg
Daily Value = 30 IU*
RDA adult men and women
Mayonnaise, 1 tbsp
Italian salad dressing, 2 tbsp
Margarine, 2 tbsp
Canola oil, 1 tbsp
Safflower oil, 1 tbsp
Sunflower oil, 1 tbsp
Peanuts, ½ oz
Peanut butter, 2 tbsp
Almonds, ½ oz
Sunflower seeds, ½ oz
Asparagus, ½ cup
Avocado, ½ cup
Wheat germ, 1 tbsp
% Daily Value
0%
10% (1.5 mg)
20% (3 mg)
30% (4.5 mg)
40% (6 mg)
50% (7.5 mg)
100% (15 mg)
Peanut Butter
*Approximately 16.8 mg if half is from synthetic and half is from natural sources.

Vitamin E Need

- RDA for vitamin E is 15 mg/day of α-tocopherol
- Recommendation based on amount needed to prevent red blood cell membranes breakdown called hemolysis
- 15-mg allotment is equivalent to
  - 22 iU of a natural source
  - 33 iU of a synthetic source of vitamin E
- Food & supplement labels often report vitamin E activity in iUs
- Converting iUs of vitamin E in synthetic form to milligrams
  - 1 iU equals about 0.45 mg for synthetic source
  - 1 iU equals 0.67 mg for natural source

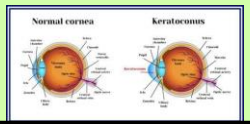
Vitamin E - Functions

- Tocopherols act as antioxidants
- Protect fats and oils from becoming oxidized
- Antioxidant activity:
  - Discourages plaque build up on artery walls
  - Discourages formation of blood clots responsible for heart attacks and strokes
- Strong protective role in reduction of atherosclerosis



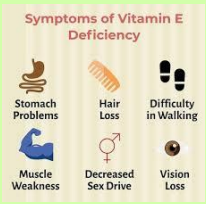
Vitamin E Functions

- Boosts immunity by improving immune system
- Protects body against cell damage thus reduces body's ability to fight infection
- Protects against cataracts as antioxidant activity of vitamin E reduce risk by 50 % or more
- Vitamin E destroy free radicals that help initiation and promotion of cancer
- Helpful against Alzheimer's Disease (degenerative disease of nerves leading towards deterioration of mental faculties)
- Anti-aging factor



Vitamin E - Deficiency

- Stored in adipose tissue and plays vital role in fertility
- Chronic deficiency leads towards
  - Reproductive disorders
  - Abortions
  - Miscarriages
  - Male or female sterility
- Degenerative diseases of nervous system and damage to liver
- High doses are not found toxic



Vitamin E Stability in food

- Easily destroyed by heating food at more than 100°C
- Activity lost during processing of vegetable oils to margarine and shortening
- Also extensively decreased if auto-oxidation of lipids in foods is severe

Vitamin E Toxicity

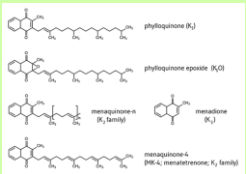
- Vitamin E relatively non-toxic
- Excessive amounts interfere with vitamin k activity
- Excessive intake leads insufficient clotting and risk of hemorrhage
- Risks particular in individuals taking daily aspirin or anticoagulation medications as warfarin to prevent blood clots
- Upper level for vitamin E set
  - 1000 mg (1500 iU) of α-tocopherol from natural sources
  - 1100 iU from synthetic sources

Vitamin K

- Fat soluble vitamin
- "Vitamin K" named after koagulation, Danish spelling for coagulation
- Compounds known vitamin K or quinones
- Vitamin K activity found in fat-soluble naphthaquinone derivatives
- 5 forms are known
- K–1
- K–2
- K–3
- K-4
- K–5
- K–1 (phylloquinone) yellow, viscous oil, present naturally in plants

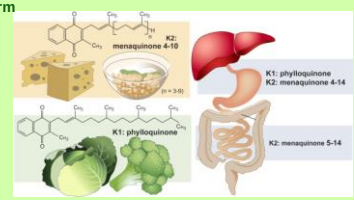
Vitamin K-Cont..

- K–2 (menaquinone) synthesised by bacteria present in intestinal tract of humans and animals about 75% as active as K–1
- Menaquinones (vitamin K_2) found in fish oils and meats
- K–3 (menadione) - synthetic product
  - crystallises as yellow needle from alcohol & petroleum ether
- K–4 also synthetic product
  - can be used by intestinal bacteria to make K–2
- K–5 also synthetic product



Vitamin K

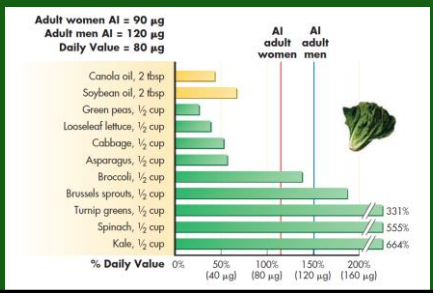
- A synthetic compound, called menadione, can be converted to menaquinone in body tissues
- **Phylloquinone**, main dietary form of vitamin, is most biologically active form



Vitamin K - Sources

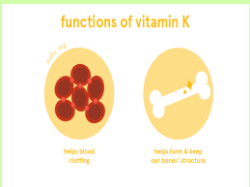
- About 10% of vitamin K absorbed each day come from **bacterial synthesis in colon**
- Good sources
- Cauliflower
- Green leafy vegetables (cabbage, kale, spinach)
- Peas
- Olive and soybean oils
- Beef liver and green tea
- Produced by bacteria in intestines
- Vegetable oils, such as soy and canola

Vitamin K Needs



Vitamin K - Functions

- **Antihemorrhagic**
- Protects excessive bleeding in cuts, wounds and internal bleeding
- Used in **blood clotting** by forming prothrombin and blood clotting proteins
- Reduces excessive menstrual flow
- Required for **biosynthesis of some proteins found in plasma, bone and kidneys**



Vitamin K – Deficiency

- Deficiency rare
- Prolonged use of antibiotics disrupt vitamin k synthesis or impaired fat absorption
- Vitamin k stores low at birth, so infants at risk of defective blood clotting and hemorrhage
- Haemorrhagic condition-blood not clot readily after injury
  - Reduction of prothrombin
  - Small haemorrhages
  - Kidney disorders
- Healthy adults should not self-prescribe oral supplements of vitamin K

Symptoms of Vitamin K Deficiency
Easy bruising or bleeding
Increased risk of nosebleeds or bleeding gums
Blood in urine or stool
Heavy menstrual bleeding in women
Oozing from cuts or wounds that takes longer to stop
Weakened bones or increased risk of fractures

Vitamin K - Stability

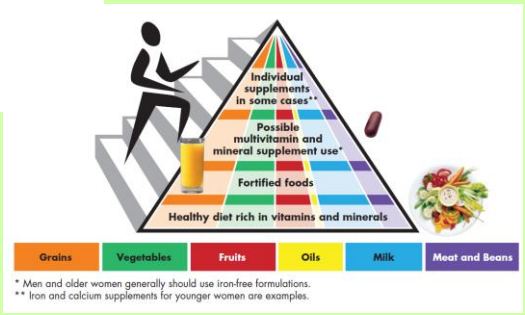
- **Photo-reactive**
- Not easily destroyed by heat or exposure to air
- Destroyed **by strong acids, alkalis and oxidizing agents**

Summary of the Fat-Soluble Vitamins

Major Vitamin	Functions	Deficiency Symptoms	People at Risk	Sources	RDA or Adequate Intake	Toxicity Symptoms
Vitamin A						
Preformed retinoids and provitamin A carotenoids	Vision in dim light and color vision, cell differentiation, bone growth, immunity, reproduction	Poor growth, night blindness, total blindness, dry skin, xerophthalmia, hyperkeratosis, impaired immune function	Rare in U.S. but common in preschool children living in poverty in developing countries and patients with fat malabsorption syndromes	Preformed vitamin A (retinoids): liver, fortified milk, fish liver oils; Provitamin A (carotenoids): red, orange, dark green, and yellow vegetables; orange fruits	700 µg (RAE) for women and 900 µg for men	Headache, vomiting, double vision, dry mucous membranes, bone and joint pain, liver damage, hemorrhage, coma, spontaneous abortions, birth defects. Upper Level is 3000 µg of preformed vitamin A.
Vitamin D						
Cholecalciferol D_3 Ergocalciferol D_2	Maintenance of calcium and phosphorus concentrations, immune function, cell cycle regulation	Rickets in children, osteomalacia in older adults	Dark-skinned individuals, older adults with low intakes or low UV exposure, patients with fat malabsorption syndromes	Vitamin D-fortified milk, fish oils, oily fish	5–10 µg 15 µg > 70 yrs 5 µg for 19–50 yrs. 10 µg for 51–70 yrs 15 µg for > 70 yrs	Calcification of soft tissues, impaired growth, excess calcium in the blood and excretion in the urine; Upper Level is 50 µg

Dietary supplements; Healthful or harmful

- Any product intended to supplement diet containing one or more of following ingredients:
  - A vitamin
  - A mineral
  - An amino acid
  - An herb, a botanical, or a plant extract
  - A combination of any of above
- Supplement savvy
- MyPyramid approach used of nutrient supplementation
- Emphasizing bottom portion of pyramid is best option
- Extra benefits include fiber, numerous phytochemicals, and omega-3 fatty acids

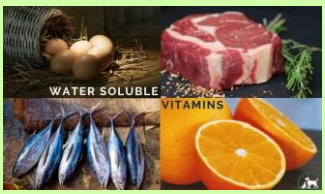

Individual supplements in some cases**
Possible multivitamin and mineral supplement use*
Fortified foods
Healthy diet rich in vitamins and minerals
Grains
Vegetables
Fruits
Oils
Milk
Meat and Beans
* Men and older women generally should use iron-free formulations.
** Iron and calcium supplements for younger women are examples.

Water Soluble Vitamins

- For centuries scurvy, pellagra, and other deficiency diseases caused enormous suffering and death
- In 20th century, scientists discovered these illness caused by absence of nutrients called vitamins
- Transfer energy and engage in protein metabolism
- Formation of red blood cells
- Natural tranquillisers or anti-stress vitamins
- Important in nerve function
- Some stored mainly in Liver, Heart and Brain
- Meet needs for up to 6 weeks
- Excess excreted through urine

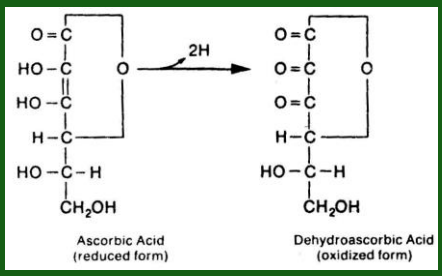
Water Soluble Vitamins

- Chemically, differ from one another
- B-group
  - Thiamine
  - Riboflavin
  - Niacin
  - Pantothenic acid
  - Folic acid
  - Biotin
  - Cyanocobalamin
  - Choline
  - Pyridoxine
- Vitamin C



Vitamin C

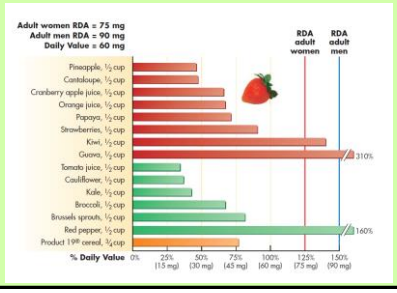
- Also known as ascorbic acid
- White, crystalline compounds, highly soluble in water
- Most animals can synthesize vitamin C, do not require a dietary source
- Humans along with some other unable to synthesize Vitamin C
- Vitamin C actually refers to ascorbic acid and oxidized form dehydroascorbic acid
- Both forms of vitamin C are found in the foods we eat



Sources of Ascorbic Acid – Cont..

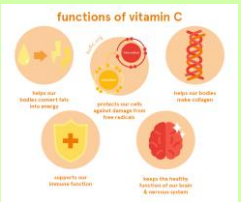
- Almost all plant foods, especially fruits, vegetables
- Rich: Fresh citrus fruits (orange, lime, grapefruit), guava, kiwi
- Moderate: Green pepper, cauliflower, cabbage, spinach, turnip, peas, tomatoes
- Poor: Dry cereals, legumes, nuts
- Deficient: Animal products

Vitamin C in Foods



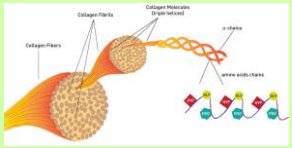
Ascorbic Acid - Functions

- Vitamin C performs a variety of important cell functions
- Collagen Synthesis
- Synthesis of Other Vital Compounds
- Antioxidant Activity
- Iron Absorption
- Immune Function



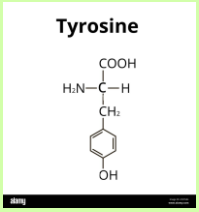
Collagen Synthesis

- Collagen, major fibrous protein holds together body structures and gives strength to connective tissue
- Collagen fibers critical to bone and blood vessels, essential in wound healing
- A collagen molecule consists of 3-polypeptide chains to form triple helix
- Vitamin C needed to get 3 strands in right shape to form helix
- Specifically, vitamin C helps convert 2 amino acids (lysine and proline) in collagen to hydroxylysine and hydroxyproline
- Vitamin C interact with metalloenzymes involved in formation of amino acids



Synthesis of other vital compounds

- Vitamin C needed for synthesis of
- Amino acid tyrosine
- Hormone thyroxine,
- Fatty acid transport compound carnitine
- Neurotransmitters norepinephrine, ephinephrine, and serotonin
- Also involved in conversion of cholesterol to bile acids and biosynthesis of hormones like
- Corticosteroids
- Aldosterone

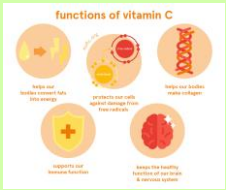


Ascorbic Acid - Functions

- Antioxidant - acts as free radical scavenger
- Prevents damage to cell by chemical cell interaction
- Acts as reducing agent in reactions occurring in respiratory chain
- Required in healing of wounds
- Strengthens blood vessels
- Strengthens dentine of teeth and bone tissues
- Aids in tooth and bone formation
- Aids in absorption of iron from intestine
- Promote immune system as WBC contain highest vitamin C concentration

Ascorbic Acid - Functions

- Some scientists claim large doses both prevent and reduce symptoms of common cold (coryza)
  - Not proved
  - Not advisable to take very large doses for long time
- Excessive consumption leads to excretion in urine:
  - unchanged
  - as dehydroascorbic acid
- Significant amount metabolised to oxalic acid
- May result in formation of some types of kidney stone
- High doses can produce stomach aches and diarrhoea



Ascorbic Acid Deficiency

- Scurvy
- Bruising and spontaneous haemorrhages under skin
- Failure of wounds and fractures to heal
- Soft swollen gums
- Bleeding gums
- Muscle fatigue
- May responsible for osteoporosis
- May responsible for anaemia
- During severe stress, demand increases due to rapid depletion of vitamin C in adrenal stores

Vitamin C Intake above RDA

- If vitamin C intake is about 100 mg/day, additional vitamin C excreted via urine
- Studies indicate 200 mg/day is highest amount needed to maximize health benefits of vitamin C intake
- Eating several vitamin C rich foods each day can boost intakes to 200 mg/day
- Higher dose of vitamin C helpful for prevention or treatment of common cold

BENEFITS OF VITAMIN C
Improves skins appearance
Supports the immune system
Helps maintain bones & cartilage
Helps with wound healing
Reduces fatigue and tiredness

Ascorbic Acid - Stability

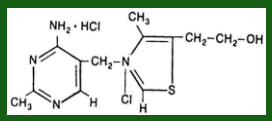
- Most sensitive easily destroyed:
- By oxidation:
  - Lost during preparatory operations like peeling, trimming, size reduction, etc
- By exposure to high temperature:
  - Conventional cooking, baking, commercial sterilisation, frying, other similar treatments
- During storage
  - Greater with increased storage temperature and period

Ascorbic Acid - Stability

- Advisable:
  - Store foods in cool, dark place
  - Handle carefully to avoid external damage
- Prepare food just prior to consumption, peeled or size reduced foods lose ascorbic acid more readily than unprepared
- Cook in minimum water for minimum time
- Do not leave prepared foods on hot plate for long periods.

THIAMINE (Vitamin B-1)

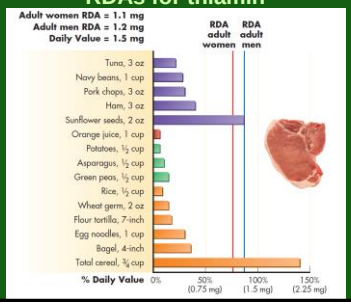
Chemistry and sources
- Thiamine
- Vitamin B-1
  - White solid
  - Highly soluble in water
- Derived from:
  - substituted pyrimidine and thiazole coupled by a methylene bridge



Thiamine (Vitamin B-1) sources

- All cereal grains (major part including bran, germ)
- Watermelon
  Oranges
- Potatoes Peas
- Dry beans
  Nuts
- Milk Yeast
- Meat (heart, kidney and liver)
- Plant and animal tissues contain it as thiamine pyrophosphate (TPP) or cocarboxylase, and diphosphate ester of thiamine

RDAs for thiamin



Thiamine - Functions

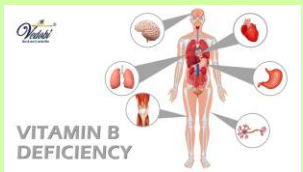
- Rapidly converted to active form, thiamine pyrophosphate (TPP) by enzyme, thiamine diphosphotransferase
- Participates in breakdown and oxidation of glucose and metabolism of pyruvic acid
- Helps body cells obtain energy from food
- Keeps nerves in healthy condition
- Promotes good appetite and digestion

Thiamin - Deficiency

- Shortage of energy
- Lesions of nervous tissues
- Earliest symptoms:
  - Constipation
  - Appetite suppression
  - Nausea
  - Mental depression
  - Peripheral neuropathy
  - Fatigue

Thiamin - Deficiency

- Chronic deficiency results
  - Ataxia (defective muscular control resulting irregular and jerky movements)
  - Mental confusion
  - Loss of eye coordination
- Result:
  - Muscular weakness
  - Palpitation of heart
  - Degeneration of nerves owing to accumulation of pyruvic acid



Thiamin - Deficiency

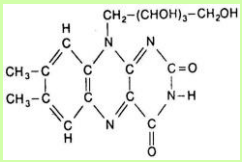
- Beriberi - prevalent where polished rice staple food
- It affects heart and circulatory system leading towards heart failure, damages nerves and decreased muscle strength eventually, muscle paralysis
- Wernicke-Korsakoff syndrome;
- Commonly found in chronic alcoholics due to poor dietetic lifestyle
- Results brain damage in lower parts called thalamus and hypothalamus
- Permanent damage to brain areas involve with memory

Thiamine - Stability

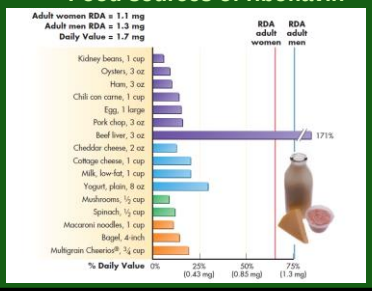
- Lost during washing
- Lost in cooking water discarded afterwards
- Sensitive to high temperature, above 100°C and partially lost during boiling, cooking, canning, roasting and baking
- Sulphur dioxide, sulphites and alkaline substances (sodium bicarbonate) especially detrimental

Riboflavin - Vitamin B-2

- Yellow, crystalline, water-soluble
- Occurs naturally as:
  - Free compound
  - Coenzyme, flavin adenine dinucleotide (FAD)
- Good sources include
- Cereals
- Liver, kidney, heart and lean meat
- Eggs
- Milk
- Cheese
- Dried brewer's yeast
- Dark leafy vegetables



Food sources of riboflavin



Riboflavin Functions

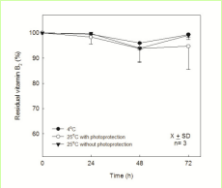
- Precursor for coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD)
- Involved in release of energy in cells
- Hence, helps utilise oxygen to liberate energy from food
- Keeps eyes healthy and skin around mouth and nose smooth

Riboflavin - Deficiency

- One cause of glossitis in man
  - Tongue and lips swollen
  - Scaliness at corners of mouth
- Deficiency often seen in chronic alcoholics - poor dietetic habits

Riboflavin Stability

- Less soluble in water
- More stable to heat than thiamine
- Losses during processing less than thiamine
- Destroyed more easily under acid than alkaline conditions
- Particularly sensitive to light
- Lost if food exposed to sunlight



Niacin (Vitamin B-3)

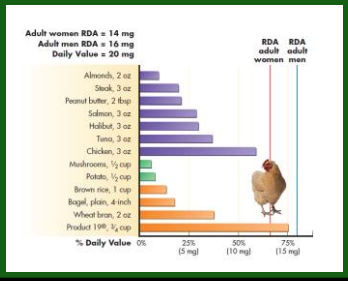
- White, crystalline compounds
- Exists as nicotinic acid, nicotinamide or as nicotinamide coenzymes:
  - Nicotinamide adenine dinucleotide, NAD
  - Nicotinamide adenine phosphate, NADP
- Both NAD^+ and $NADP^+$ function as cofactors for lactate, malate and other dehydrogenases
- Body converts nicotinic acid to nicotinamide
- Can also be formed from tryptophan

Niacin Sources

Widely distributed in plant and animal foods
Especially rich

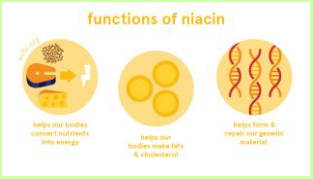
- Liver, lean meat, poultry, fish
- Leafy vegetables
- Beans, peas, legumes, groundnuts
- Whole grain cereals
- Enriched breads
- Brewer's yeast

RDA of Niacin



Niacin - Functions

- Involved in oxidation of glucose
- Helps body cells use oxygen to produce energy (cellular oxidation)
- Involved in maintenance of health of skin, tongue, digestive tract and nervous system

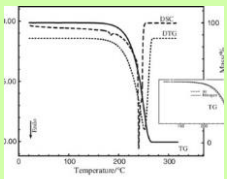

functions of niacin
helps our bodies convert nutrients into energy
helps our bodies make fats & cholesterol
helps form & repair our genetic material

Niacin – Deficiency

- Deficiency causes pellagra
- Symptoms:
  - Diarrhoea
  - Weight loss
  - Dermatitis - scaling and discolouration of part of skin exposed to sun
  - Dementia - mental disorders
- Deficiency also linked and responsible for protein shortage

Niacin Stability

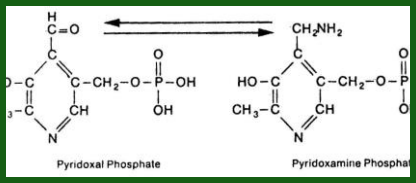
- One of most stable vitamins
- Relatively resistant to heat, acid or alkali
- Losses through trimming, leaching, etc., almost parallel other water-soluble vitamins
- Small amounts lost in water discarded after cooking cereals, meat and other foods containing this vitamin



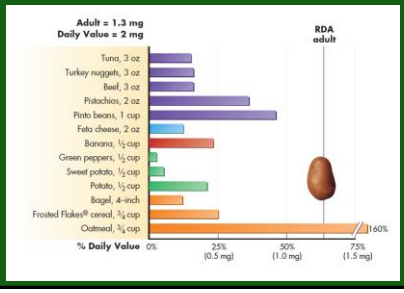
DTG and DSC curves obtained at 10 °C/min a
for niacin

PYRIDOXINE (Vitamin B-6)

- Pyridoxine, pyridoxal and pyridoxamine related compounds referred as vitamin B-6
- All compounds efficiently converted to biologically active form B-6, pyridoxal phosphate
- Pyridoxine crystalline, very soluble in water and soluble in alcohol
- Sources - Rice bran, yeast, cereals, egg yolk, meat, liver, kidney, fish, cauliflower, green pepper, potatoes and spinach

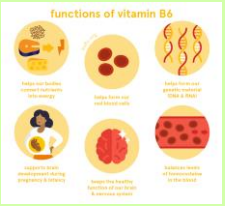


Food sources of vitamin B-6



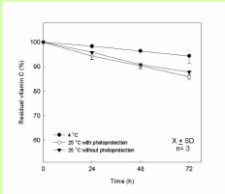
Pyridoxine Functions

- Cofactor in enzyme system as pyridoxal phosphate involved in transamination reactions, vital step in amino acid metabolism
- Requirement proportional to level of protein consumption
- Deficiency very rare, results in nervousness and insomnia
- Occurs mainly in infants fed on pyridoxine-deficient baby foods



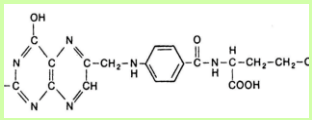
Pyridoxine - Stability

- Vitamin B-6 lost in sterilised milk, possibly due to its reaction with cysteine resulting formation of biologically inactive substance
- Sensitive to light, especially in presence of oxygen



Folic Acid

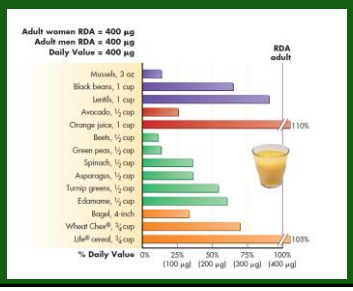
- Folic acid group given to pteroylglutamic acid and derivatives that have vitamin activity
- Crystallises from water as yellow-orange needles
- Slightly soluble in cold water, soluble in hot water and insoluble in ether
- A conjugated molecule consisting of pteridine ring structure linked to □-aminobenzoic acid and glutamic acid



Folic Acid - Sources

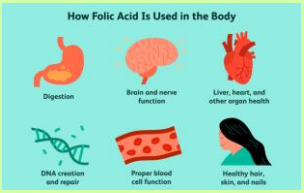
- Present in animal and plant foods
- Abundant in green leafy vegetables
- Good sources
  - Pulses, organ meats, liver, egg yolk
- Poor sources
  - Cereal grains, milk

Food sources of folic acid



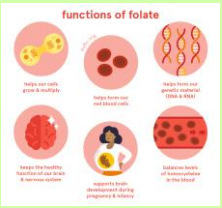
Functions of folic acid

- Active form tetrahydro folic acid is important in metabolism and transfer of one carbon units - methyl, methylene, methenyl, formyl, or forminino groups
- These one carbon transfer reactions required in biosynthesis of:
  - Purines
  - Pyrimidines
  - Amino acids like serine, methionine and glycine


How Folic Acid Is Used in the Body
Digestion
Brain and nerve function
Liver, heart, and other organ health
DNA creation and repair
Proper blood cell function
Healthy hair, skin, and nails

Folic Acid - Functions

- Involved in synthesis of new cells
- Helps in:
  - Production of nucleic acids (DNA and RNA)
  - Formation of red blood cells



Folic Acid Deficiency

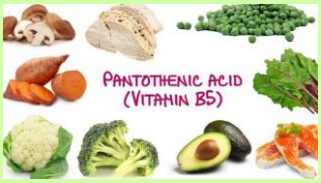
- Most pronounced effect on cellular processes upon DNA synthesis
- Result:
- Megaloblastic anaemia- decreased synthesis of red blood cells
- Second most common type of nutritional anaemia after iron deficiency
- Anaemics:
- Usually weak
- Unable to engage in strenuous exercise
- Unable to engage in sustained exercise
- Chronic alcoholics also suffer from folate deficiency

Folic Acid - Stability

- Readily degraded by:
  - Light
  - UV radiation
- Folic acid lost in milk packed in glass bottles left in light, through oxidation
- During cooking most folate destroyed

Pantothenic Acid

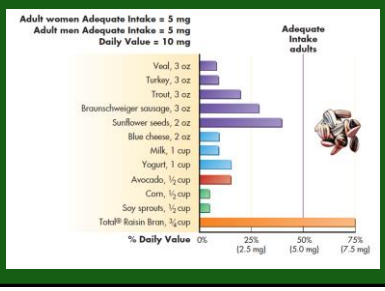
- Yellow viscous oil
- Extremely hygroscopic
- Highly soluble in water
- Formed from □-alanine and pantoic acid
- Calcium pantothenate, usual commercial form:
  - White microcrystalline salt
  - Soluble in water



Sources of Pantothenic Acid

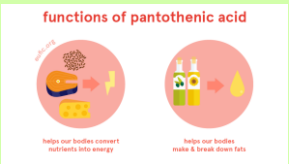
- Found in all foods except sugar, fat, distilled alcoholic beverages
- Rich sources
  - Liver, kidney, heart, brain, egg yolk, yeast, fresh vegetables
- Good sources
  - Groundnuts, whole cereal grains, lentils, and mushrooms

Food sources of pantothenic acid



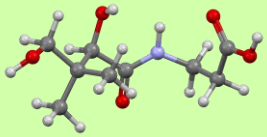
Pantothenic Acid - Functions

- Required for synthesis of coenzyme A (CoA)-component of acyl carrier protein (ACP)
- At least 70 enzymes identified requiring CoA or ACP derivatives for their function
- Coenzyme A concerned with metabolic processes involving removal or addition of an acetyl group ($-COCH_3$)
- Participates in metabolism of:
  - Fats
  - Proteins
  - Carbohydrate
- Deficiency rare as found in variety of plant and animal tissues



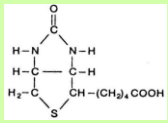
Pantothenic Acid Stability

- Readily destroyed by:
  - Acids
  - Bases
  - Heat
- More stable in pH range 4 to 7
- In thermally processed foods:
  - Losses in excess of 50%

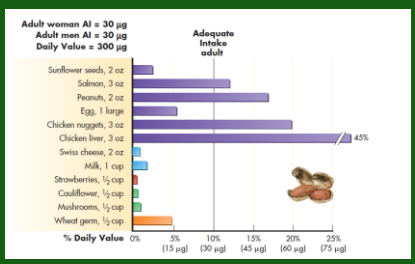


Biotin or Vitamin H

- Water-soluble
- Crystallises in needles from water
- Sources:
- Wide variety of foods - Egg yolk, liver, yeast, legumes, wheat germ, poultry
- Also synthesised by bacteria present in intestinal tract
- Hence not mandatory dietary requirement

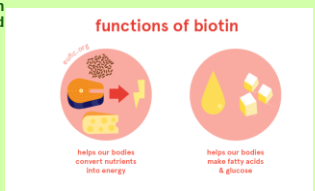


Food sources of Biotin



Biotin Functions

- Participates in carboxylation and transcarboxylation reactions as co-enzymes:
  - Acetyl-CoA carboxylase
  - Pyruvate carboxylase
- Involved in metabolism of
  - Fats
  - Proteins
  - Carbohydrates

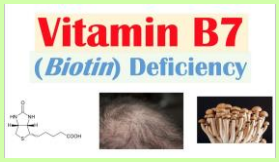


Biotin Deficiency

- Generally longer antibiotic therapies, deplete intestinal fauna
- Excessive consumption of raw eggs- biotin combines with avidin, a protein in raw egg white
- Cooking egg white prevents this reaction

Biotin –stability

- Stable to Heat and Light
- Unstable in:
  - Strong acidic conditions
  - Strong alkaline conditions
- Optimum stability in pH range 5–8

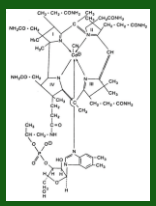


CYANOCOBALAMIN (B-12)

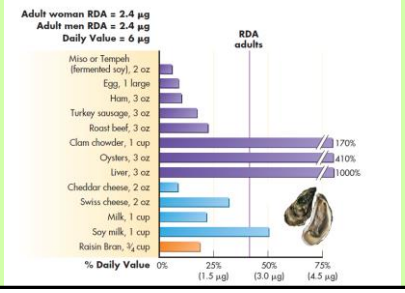
- Chemistry
- Structurally complex compound
- Composed of:
  - Complex tetrapyrrol ring structure (corrin ring) with Co ion in centre
- Water-soluble compounds
- Red in colour

Sources of Cyanocobalamin (B-12)

- Synthesised by microorganisms in fermented foods especially vegetables
- Found mainly in foods of animal origin:
  - Tuna
  - Clams
  - Crab
  - Mussels
  - Oysters
  - Liver

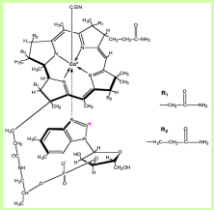


Food sources of vitamin B-12



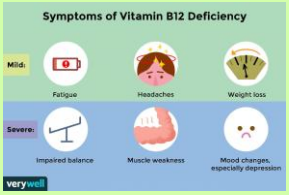
Cyanocobalamine - Functions

- Necessary for growth and formation of red blood cells
- Deficiency:
- Result of failure to absorb or utilise B-12, not absence in diet
- Dietary deficiency in strict vegetarians
- Deficiency also occurs in people consuming raw or undercooked fish that contains tapeworm, Diphyllobothrium latum.
- This inhabits intestines of man and removes B-12 from food of host



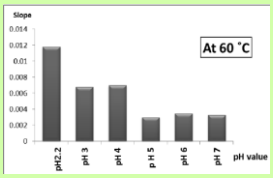
Cyanocobalamine deficiency

- Results in pernicious anaemia, a form of megaloblastic anaemia
- Neurological complications also associated with vitamin B-12 deficiency
- Result from progressive demyelination of nerve cells



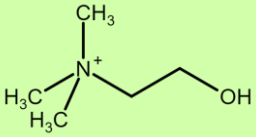
Cyanocobalamine - Stability

- Quite stable in pH range 4–6
- Only small losses occur in this range even after heat processing
- At higher pH or in presence of reducing agents, such as ascorbic acid or sulphite, losses may be severe



Choline-B group vitamin

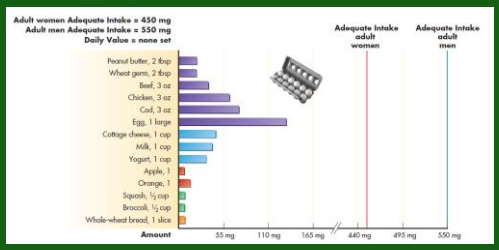
- Often included in supplements as a "supposed" B-vitamin
- Choline not yet confirmed as B vitamin
- Does not have coenzyme function and choline amount in body is much greater than amount of typical B-vitamin
- Choline is widely distributed in foods of animal origin, mostly in phosphatidylcholine (lecithin) form in cell membrane and blood lipoproteins
- Milk, Liver, eggs, peanuts are rich sources



Functions of Choline

- Choline can be used to synthesise glycine, an amino acid
- Component of phospholipids, such as phosphatidylcholine (lecithin), major component of cell membranes and blood lipoproteins
- Acts as lipotropic factor
- Precursor of aacetylcholine, neurotransmitter associated with attention, learning, memory, muscle control, and many other functions
- Involved in export of VLDL in Liver

Food sources of choline



Summary of water soluble vitamins

Vitamin	Major Functions	Deficiency Symptoms	People Most at Risk
Thiamin	Coenzyme in carbohydrate metabolism and energy release	Beriberi: anorexia, weight loss, weakness, peripheral neuropathy; Wernicke-Korsakoff syndrome	Alcoholics and people living in poverty
Riboflavin	Coenzyme in numerous oxidation-reduction reactions, including those of energy release	Ariboflavinosis: inflammation of mouth and tongue, cracks at corner of mouth	People taking certain medications if no dairy products are consumed
Niacin	Coenzyme in numerous oxidation-reduction reactions in energy metabolism, synthesis and breakdown of fatty acids	Pellagra: diarrhea, dermatitis, dementia (death)	Alcoholics and people living in poverty where corn is the dominant food
Pantothenic acid	Coenzyme in energy metabolism and fatty-acid synthesis	Weakness, fatigue, impaired muscle function, GI tract disturbances; deficiency very rare	None
Biotin	Cofactor for carboxylase enzymes that participate in fatty-acid, amino acid, and energy metabolism	Dermatitis, conjunctivitis, hair loss, nervous system abnormalities; deficiency very rare	Infants with a certain genetic defect
Vitamin B-6 (pyridoxine)	Coenzyme in amino acid metabolism, heme synthesis, lipid metabolism; homocysteine metabolism	Dermatitis, anemia, convulsions, depression, confusion	Alcoholics

Summary of water soluble vitamins

Folate	Coenzyme in DNA synthesis, homocysteine metabolism	Megaloblastic (macrocytic) anemia, birth defects	Alcoholics, pregnant women, people on certain medications
Vitamin B-12 (cobalamin)	Coenzyme affecting folate metabolism, homocysteine metabolism	Megaloblastic (macrocytic) anemia, paresthesia, pernicious anemia	Older adults, vegans, patients with malabsorption syndromes
Vitamin C (ascorbic acid)	Collagen synthesis, some antioxidant capability, hormone and neurotransmitter synthesis	Scurvy: poor wound healing, pinpoint hemorrhages, bleeding gums	Alcoholics, individuals who eat few fruits and vegetables, smokers
Choline	Precursor for acetylcholine and phospholipids; homocysteine metabolism	No natural deficiency	None